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SURFACE SOIL DYNAMICS DUE TO BAKOLORI DAM CONSTRUCTION ALONG SOKOTO RIVER CHANNEL IN THE SOKOTO-RIMA RIVER BASIN

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Abstract:

This Paper is an assessment of the downstream response of the surface soil of the Sokoto River channel sequel to the construction of the Bakolori dam in the late 1960's. It adopted several methods including systematic and purposive sampling techniques for choosing the sample sites during the reconnaissance survey; onsite field observations and measurements for data collection and the use of secondary information which lasted over 24 months (June, 2007 - November, 2008). The soil survey and land classification report (FAO, 1969) and previous studies as well as laboratory and GIS analysis of data provided the needed inferences. The hypothesis that the Bakolori dam has not caused significant changes in the surface soil characteristics of the Sokoto River storm channel, were tested using the analysis of variance (ANOVA). The results revealed significant changes in the surface soil characteristics between pre dam and post dam conditions, showing a significant impact of the dam on the variables. Consequently, the working hypothesis was rejected. However, using the concept of Cumulative Effect, it was concluded that the Bakalori dam has significant effect on the Sokoto river storm surface soil characteristics but with other factors playing roles in the final outcome.

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Introduction

The nature of hydrological effects varies with the structure, management and purpose of a dam and the seasonal regime of the affected river. Dams come in many different shapes and sizes. A critical distinction between types of dams reflects their purpose. Dams for irrigation for example, cause moderate variations in flow regime on a longer timescale, storing water at seasons of high flow for use at times of low flow. The critical point is that most dams moderate and delay the incoming flood peak because of the flood-routing effect of the storage. Such effects can be particularly significant where river regime is flashy and such peaks are common, for example in rivers in the semi-arid tropics and sub-humid areas (Olofin 1994).

This paper presents the study of the surface soil of River Sokoto storm channel downstream of the Bakolori dam, which is located about 110 km upstream the river, near Talata-Mafara, The Sokoto Basin lies in the sub-Saharan Sudan belt of West Africa with a Savanna-type vegetation generally classified as semi-arid. It lies between latitudes 10 ° and 14 ° N and longitudes 3 ° and 7 °E and covering an area of about 65,000 square kilometers (Fig.1) and placed on the Iullemmeden Basin of West Africa covering an estimated area of 700,000km2 (Kogbe, 1989) extends into northwestern Nigeria where it is referred to as the .Sokoto Basin..This study of the relationship between the Bakolori Dam, constructed over 30 years ago, provided scientific facts on the roles of individually existing variables, such as a dam, as they affect the environmental responses particularly the surface soils.

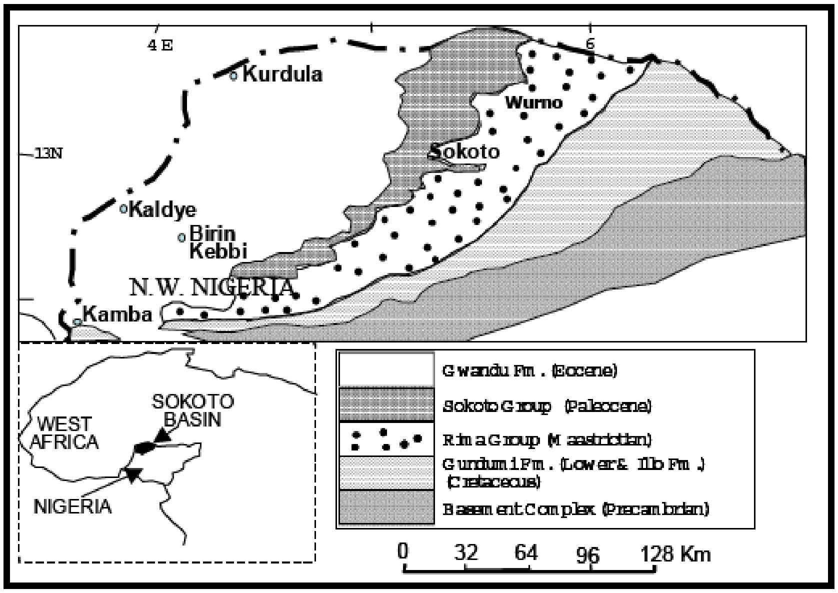

Fig. 1 Geological map of Sokoto sedimentary basin, NW Nigeria (Modified from Oteze, (1991)

Methods

The reconnaissance survey allowed for identification, familiarization and mapping of the area studied. During this period, the sample sites BD1 (Lat.12^{0}41'N Long.5^{0}51'E); BD2 (Lat.12^{0}56'N Long.5^{0}40') located geologically on the Dukamaje formation in the Rima Group.; and BD3 (Lat.13^{0}00'N Long.5^{0}18'E) located geologically on Kalambaina formation of the Sokoto group were identified along the approximately 128 km length of the river. Using purposive sampling technique, (sampling where the investigator merely hand picks those cases considered to be typical or where they are likely to posses the desired set of information or characteristics for inclusion in the sampling), an additional site BD4 (Lat.12^{0}55'N Long.5^{0}42') located on the Gundumi formation was taken because of a curve that surely provided detailed information on sedimentation and erosion. (Fig. 2)

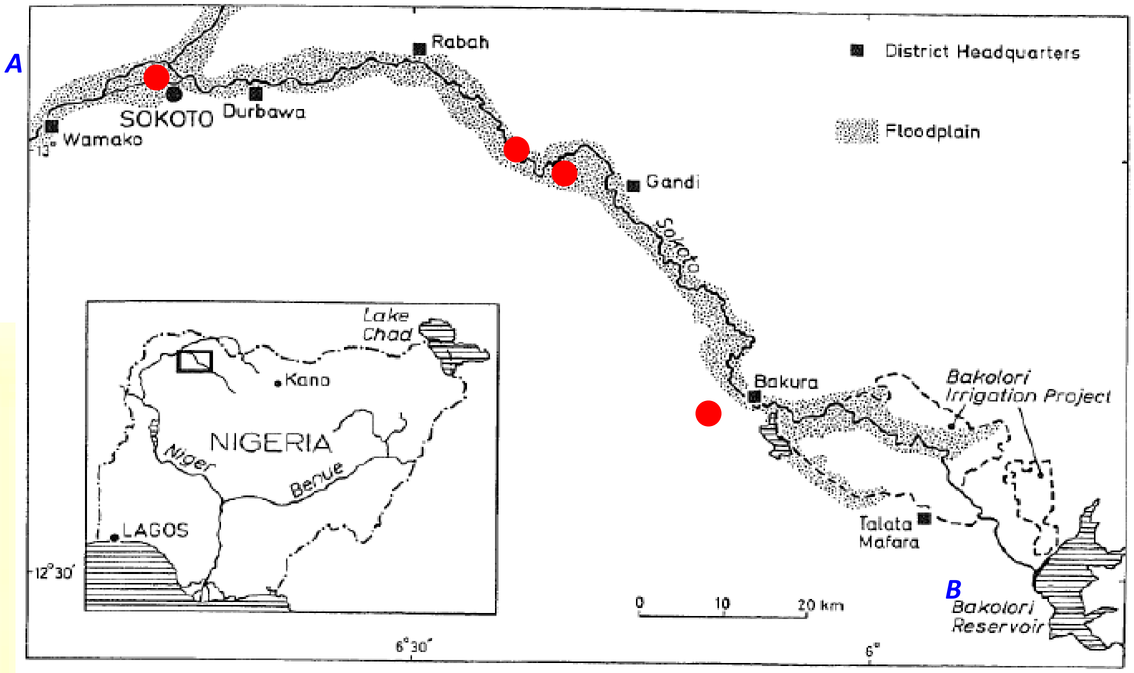

Fig. 2 Location of the Sampling Sites Down stream reaches of Bakolori Dam (along River Sokoto A-B) adopted from Kogbe (1979).

LEGEND

* Major Rivers and Tributaries

* ■ Major Villages along the channel

* ● Sample sites

Data collection included ones from primary and secondary sources. The primary sources of data were combinations of observations, measurements and laboratory analysis as explained later. Secondary information and data were collected through the pre-dam surveys, the existing literature on the study area and other similar studies across the globe reported in academic journals and books, as well as documents from the Sokoto-Rima River Basin and the FAO 1969 pre- dam report of the basin. The internet and exiting topographic maps were also very useful.

Data collection and analysis was done with specific adherence to strict procedures of bservation and recording. Surface Soil samples were initially taken from BD1-3 and BD4 for physical and chemical analysis. Using the method in the National Soil Handbook 430 VI by USDA (1983) and the reviewed soil analysis manual by FAO, 2006, the surface soil characteristics of the areas were observed adequately and recorded in the field. The field methods were followed by laboratory analyses which included particle size analysis using Buoyoucos hydrometer method and textual classes determination, using the USDA soil triangle. Others are soil texture using special soil sieves with meshes of different grade was used; soil pH-values, using pH meter after equilibrating in 1:1 soil water suspension; Organic carbon, determined by the Walkley-Black wet oxidation method; exchangeable bases, Ca, Mg, K and Na were extracted using NH_4OAC (pH 7.0) (Ezenwa and Esu 1999). Calcium and magnesium were determined by 0.01N EDTA titration methods, (Mclean, 1965), while Sodium and Potassium were determined by flame photometer. Finally, the Cat ion Exchange Capacity of the samples were ascertained using neutral ammonium acetate (NH_4OAC).

Thus, the comparisons of historical data with the current information allowed us to determine the long term effects of the Bakolori dam on the surface soil. Changes were assessed in terms of magnitude, timing and rate. To this end, the mean values of pre-dam surveys (FAO, 1969) and that of the post dam (2007) surface soil samples were compared. Only the pre-dam data characteristics along the Sokoto River, of areas that tally with the sampled sites BD1-BD3 and BD4 were however used for the comparison.

Result and Discussion

Characteristics at BD1/K1 (BD for post-dam and K1 for pre-dam)

Table 1 shows the pre-dam data (FAO, 1969) and the 2008 field result for the surface soil at the sample site.

Table 1 Comparison of the properties for pre and post dam surface soils at BD1/K1

VARRIABLES	PRE-DAM, 1969	POST-DAM, 2007
Texture	Fine sands	Sandy loam
Structure	Weak sub angular, blocky	Strong coarse sub angular blocky
Colour	Brown (10YR 5/3)	Brownish yellow (10YR 4/4)
Consistence	Friable (moist)	Friable (moist)
PH	5.0	6.62
CEC	6cmolkg^{-1}	37cmolkg^{-1}
Organic carbon	0.4g/kg^{-1}	5.95g/kg^{-1}

From the table it is observed that the fine sandy characteristics of the sample site K1 (1969) could be explained by the continuous normal flow of water along the channel, while the abrupt change of water velocity caused by the construction of the dam aided an increased deposition of fine light particles (silt and clay) that hitherto would have move down the channel, and thus changing the texture to sandy loam.

From the two surveys (1969 and 2007) soil structure has not changed, but structurally stable in the post dam than pre dam. The damming of the river and the consequent reduction in velocity of the water flow might have allowed for a stronger structural development. Strong soil structure may also be explained as a result of the addition of fine materials that binds the soil together. Colour change from brown in pre dam period to brownish yellow in the post dam period was observed. Changes in colour of soil have been attributed to factors such as the mineral contents, humus and oxygen status. The change observed here could partly be due to the deposition of organic matter as a result of reduced velocity of water flow.

The pH values of the top soil at K1/BDI for 1969 & 2007 (Figure 3) shows a clear difference of 5.0 (1969) and 6.62 for (2007), an indication that the acidity of a soil has been affect the flow characteristic of a river overflowing the soil due to the nearest deposit of hummus with lesser acidic characteristics.

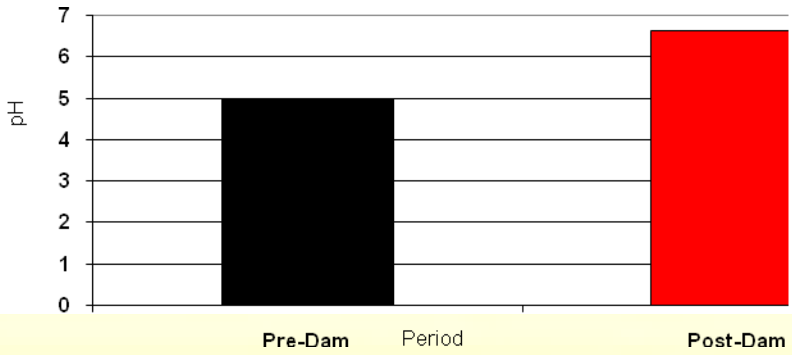

Fig. 3 Pre and Post Dam Soil pH Differences BD1/K1

The result for the pre dam indicates slight acidity while the post dam result indicates near neutral reaction. The increase in pH may be attributed to the deposition of salt, a major problem of irrigated areas. The difference in the CEC can be attributed to the changes in clay content of the soil at the sample site, as soils with high CEC shows that they have significant clay or organic content. There are apparently increased clay and humus contents due to the multiplier effect of the dam construction, which brought a shift in the characteristic of the soil by abrupt deposits of higher fine particles that would have reached the tail of the river.

Characteristics at BD2/F1 (BD2 for post-dam and F1 for pre-dam)

Table 2 shows the pre-dam data (FAO, 1969) and the 2008 field result for surface soil at the sample site.

Table 2 Composition of the Soil Properties of Pre and Post Dam samples at BD2/F1

VARRIABLES	PRE-DAM, 1969	POST-DAM, 2007
Texture	Fine sand	Sandy loam
Structure	Weak medium angular blocky	Strong coarse sub-angular blocky
Colour	Reddish brown	Brown (10YR5/3)
Consistence	Friable when moist	Friable when moist
PH	5.6	7.77
Organic Carbon (gkg^{-1})	NA	4.7
CEC ($cmolkg^{-1}$)	2	39.6

Soil texture in pre dam survey was fine sand while in the post dam it changed to sandy loam. Deposition of fine materials as earlier observed was responsible for the change due to reduction in the flow of the water as a result of the damming, evident at site BD2/F1. Soil structure has also changed, in the pre dam it was weak medium angular blocks and in post dam it was strong coarse sub- angular blocky soil. Changing river course and deposition of fine materials might have contributed to the strong structural grade. It can be concluded therefore, that the river at this site (BD2/F1) has started to regain the pre-dam momentum. Studies by FDALR, (1985) also reported strong coarse sub angular blocky structure. However, for the organic matter content, the pre dam value was not available.

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The pre dam soil pH indicated slight acidity while the post dam pH shows slight alkaline condition. The increase in soil pH after 30 years of the dam construction could be attributed to the increased human activities (irrigation) at the river channel. Soluble salts are often deposited in irrigated areas as a result of poor drainage and high evaporation. These soluble salts may raise the pH of the soil. A reduced water volume as a result of dam construction also encourages reduction oxidation reaction, a condition which may lead to increased pH. A reduced water volume in a river channel also affect the redox reaction taking place on the flow or within the under lying soils. The cat ion exchange capacities for pre dam and post dam soils differ widely as shown in Table 2, the differences being as a result of mineral contents of the materials deposited over time.

Characteristics at BD3/B1 (BD3 for post-dam and B1 for pre-dam)

Table 3 shows the pre-dam data (FAO, 1969) and the 2008 field result for surface soil at the sample site.

Table 3 Comparison of the soil properties for pre and post dam surface soils at BD3/B1

VARRIABLES	PRE-DAM, 1969	POST-DAM, 2007
Texture	Fine sands	Sandy Loam
Structure	Weak, sub angular, blocky	Weak Sub angular blocky
Colour	Brown (10YR5/3),	Brown (10YR5/3)
Consistence	Friable when moist	Friable when moist
PH	5.0	6.05
Organic Carbon (gkg^{-1})	0.8	11.59
CEC ($cmolkg^{-1}$)	1	10.5

Soil texture was coarse in the pre dam soil characteristics and changed to sandy loam in the post dam. This is an indication of deposition of these materials as a result of reduced river flow consequent upon dam construction. There was however no change in structure and consistence of the soil at both pre dam and post dam survey. The structure and consistence remained weak sub angular blocky and friable respectively for the pre dam and post dam soils. The inference therefore, is that, the effect of dam decrease with distance downstream, as areas closer to the dam experiences more effects (Olofin, 1980). Even though he maintained that physical and ecological effects of flow regulation could be experience several hundred of kilometers downstream.

The result of the pH for the two surveys, however, shows that the pre- dam soil has higher acidic (5.0) content when compared to the post-dam value (6.05). The increase in pH is attributed to reduced volume of water as a result of dam construction. In this case evaporation often exceeds the amount of water added and such leads to the development of basic cat ions (Ca, rs, & Li) which may raise the pH of the soil. As for the CEC, the greater differences between pre dam and post dam is as a result of clay and humus content which have increased over 30years after the dam construction due to increased hummus and silt transport and deposition at the sample site particularly that, it is the confluence of rivers Rima and Sokoto.

Characteristics at BD4/K3 (BD4 for post-dam and K3 for pre-dam)

Table 4 shows the pre-dam data (FAO, 1969) and the 2008 field result for surface soil at the sample site.

Table 4 Comparison of the properties for pre and post dam surface soil at BD4/V4

VARRIABLES	PRE-DAM, 1969	POST-DAM, 2007
Texture	Loamy sand	Sandy loam
Structure	Weak medium sub angular blocky	Strong coarse sub angular
Colour	Yellowish brown (10YR 4/7)	Dark yellowish brown (10YR 4/4)
Consistence	Friable when moist	Firm
PH	4.5	7.76
Organic Carbon (gkg^{-1})	0.8	4.76
CEC ($cmolkg^{-1}$)	4.5	38.6

Soil texture has changed to coarser texture in the post dam survey. This could have been deposition by stronger water flow as a result of flooding as the river often over flood their banks during the rainy season. Structure has changed from weak structural grade and medium class to stronger and coarse structural grade and class respectively. The strong and coarse structural grade and class is an indication that the soil has had much time to form without disturbance from heavy flow by water.

Colour change from yellowish brown to dark yellowish brown is an indication of deposition of organic matter and humus. pH in pre dam soils indicates strong acidity while it is alkaline in post dam soils. Damming of the river which may have reduced the flow of water, coupled with the high evaporation in the area might have resulted to deposition of basic cat ions such as Ca^{2+}, mg^{2+}, K^{+}. Irrigation activities as a result of damming bring about salt deposit and hence increase in soil pH.

GENERAL COMPARISON OFG THE SAMPLE SITES

The cat ion exchange capacity (CEC) also shows a great difference between 4.5 (pre) and 38.6 (post) dam data. There is, as evident in the data, high amount of finer particles (clay and hummus) during the post-dam survey. This is attributed to the dual effect of regulated water flow whose velocity is highly reduced thereby increasing sediment yield at the site and the meandering effect of the site also reducing the rate of flow and affecting the sediment transportation.

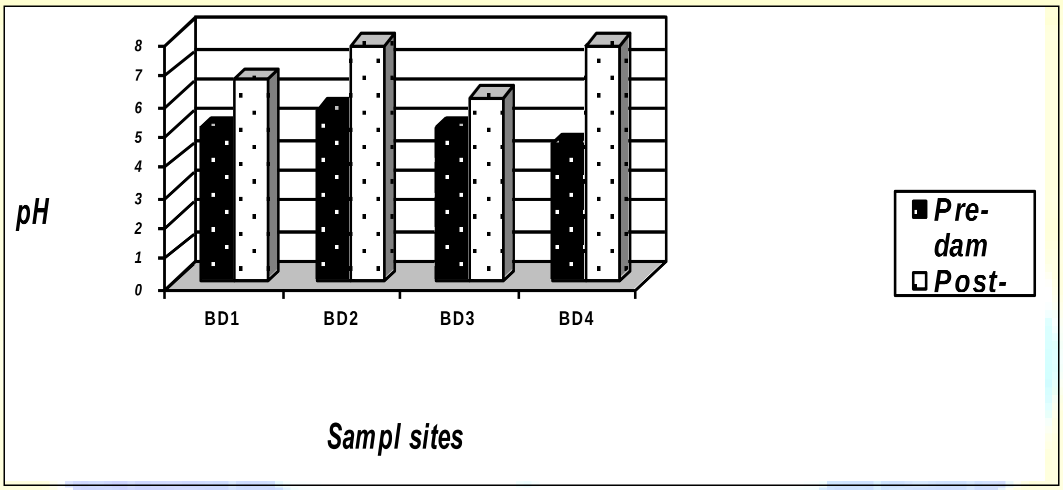

Figure 4 Variation in Pre and Post dam surface soil pH

The t-value measuring the difference between the pre – and post-dam pH is 17.481 While the theoretical values is 5.9874, Thus, this is an indication that there is a significant difference in the pH of the pre and post dam soils. There is also significant difference in the cat ion exchange capacity of the soils which shows a t-value of 15.7995 and a theoretical value of 5.9874.

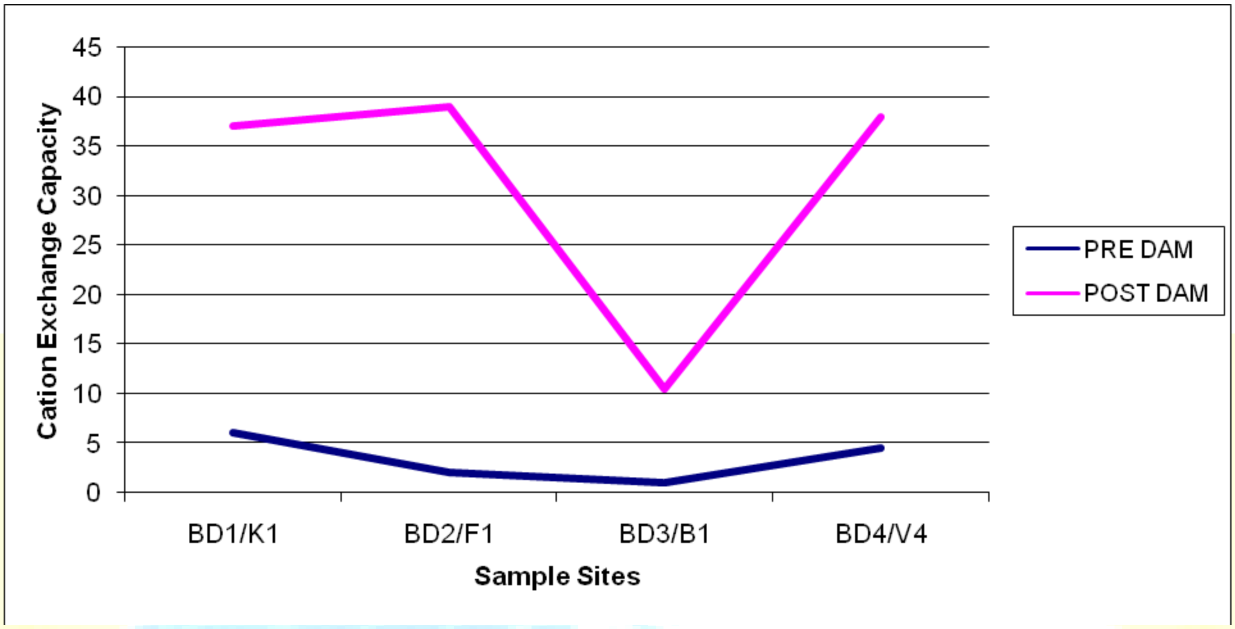

Figure 5 Variation in pre and post dam CEC

The analysis of the organic matter content for the study area reveals a t- value of 2.8856 and a theoretical value of 5.9874. This implies that there is no significant difference for pre and post dam values.

Conclusion

From the statistical analysis using the Analysis of Variance (ANOVA) it is evident that after over 30years of the construction of the Bakolori dam, tremendous and significant changes have taken place on and within the soil constituents along the Sokoto river channel downstream of the dam. These, as we have seen, are noticeable both in the chemical and physical aspects of the surface soil characteristics. It is also technically correct to state that the abrupt change of water velocity caused by the construction of the dam aided an increased deposition of fine light particles (loamy) that hitherto would have move down the channel.

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